Methanol (MeOH) / Dimethyl Ether (DME) as an Alternative Fuel for Diesel Engines

The use of MeOH/DME in diesel engines is conceivable in different ways. Promising concepts are "fumigation" and "torch ignition". In these concepts, a part of the MeOH is catalytically converted and separately introduced into the engine running on MeOH. The reactor design problems for these concepts with DME production on-board have not been solved yet, especially transient operation and cold start compatibility are a challenge. The heating-up behaviour of a reactor is calculated. It is shown that the cold start problem is solvable.

1. Introduction

Since the eighties MeOH has been used and tested as an alternative fuel in different systems, e.g. combustion engines and fuel cells.

One disadvantage of MeOH is its bad ignition behaviour in compression ignition engines. Different concepts have been developed in order to overcome this problem. Additional ignition sources (ignition spark) or additives (e.g. methyl-tert.-butyl ether MTBE, dimethyl ether DME) can be used as ignition improvers.

The application of an ignition source is problematic due to the coking danger of the spark plug.

Additives can be applied in different ways. One is the addition to the fuel before refuelling. Another way is to produce the additives onboard. The additives are then injected separately into the engine.

Another possibility is to convert all methanol to DME. DME has better ignition characteristics. The conversion can be done in large stationary plants or onboard. The dehydration reaction is described by the following equation:

$$2\ CH_3OH <=> CH_3OCH_3 + H_2O$$

2. REQUIREMENTS FOR AN ENGINE RUNNING ON NEAT DME

In this concept, DME is used as the main fuel. MeOH is catalytically converted to DME and water, and the resulting mixture is injected into the engine.

Figure 1 shows the ignition behaviour of these mixtures. The shaded area marks the concentration range where good ignition properties of the mixtures have been observed experimentally [1]. The squares within this area represent mixtures which have been tested in an engine.

The stoichiometric conversion of MeOH to DME and water according to the above reaction leads to compositions along the straight line in the diagram. The results of our own conversion experiments in liquid phase are shown as circles along this line. The equilibrium position of the chemical reaction at 500 K is presented by the star.

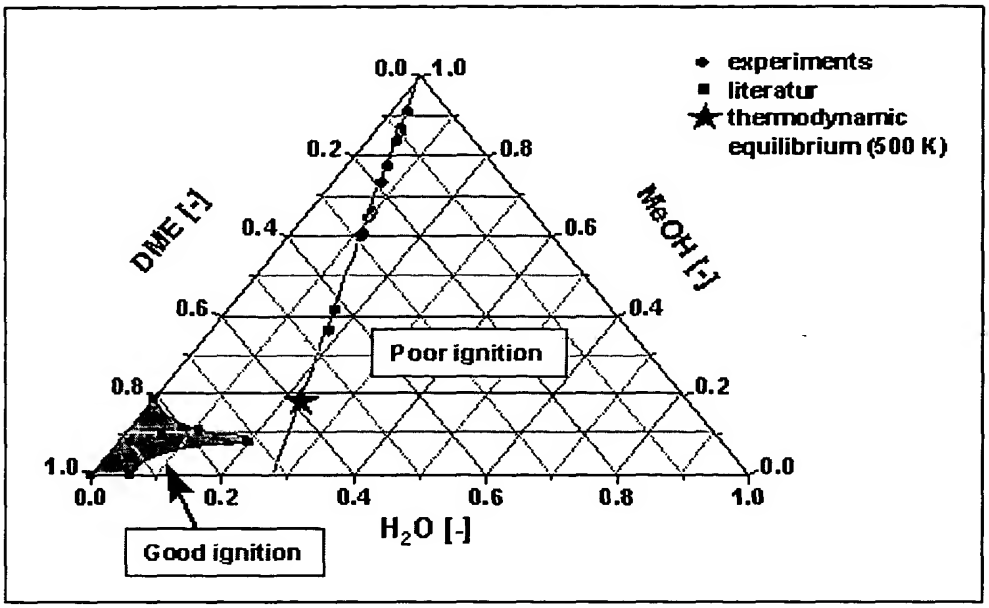

Fig. 1: Ignition characteristics of DME/MeOH/water mixtures (simultaneous injection) [1].

Figure 1 shows that the compositions which have good ignition behaviour cannot be achieved by a converter without separation of the product mixture, independently of the achievable conversion rate. Ignition is only possible if water and/or MeOH is separated from the mixture. An additional separation step after conversion is, however, connected with an additional technical effort. Therefore, the concept with conversion of all MeOH to DME, i.e. an engine running on neat DME, does not seem promising.

3. DME-FUMIGATION / TORCH IGNITION

In Figure 2, the concepts "fumigation" and "torch ignition" are schematically presented. In these concepts, a part of the MeOH is catalytically converted and separately introduced into the engine [2] running on MeOH. If a conversion rate of approx. 80 % is achieved, the reaction mixture can be injected without separating a component [3,4]. Due to the small mass flows of MeOH, the conversion can be performed in the gaseous phase.

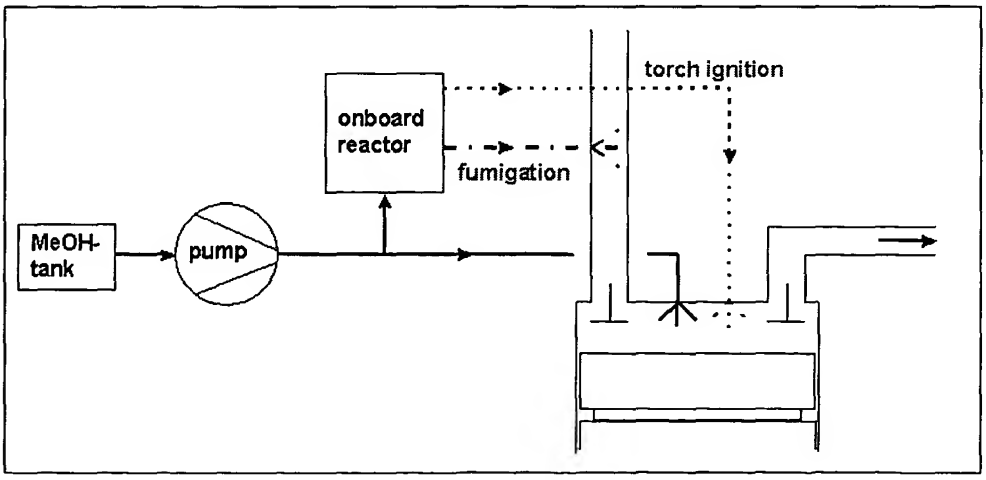

Fig. 2: Scheme of "fumigation/torch ignition".

4. PRELIMINARY CATALYST SCREENING RESULTS

Figure 3 presents the results of our screening experiments with g-Al_2O_3. The experiments show that a conversion of MeOH higher than 80 % is possible at a temperature of 573 K. These results confirm the results of [5].

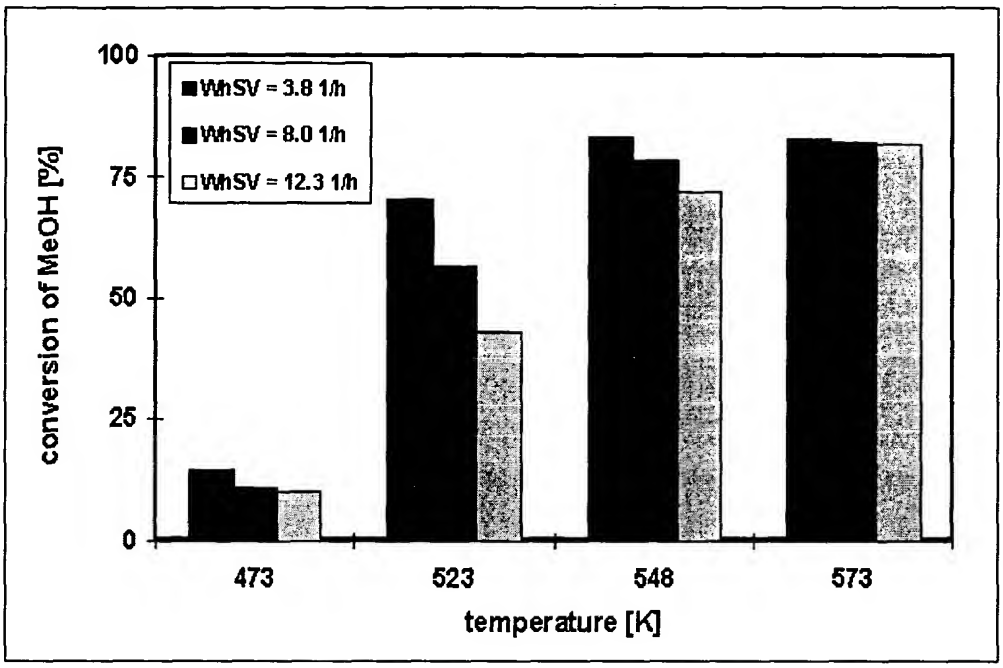

Fig. 3: MeOH conversion as a function of various temperatures and WhSV.

The concepts "fumigation" and "torch ignition" are found to be promising alternatives to neat DME, especially since the emission levels obtained from engines running on fumigated MeOH are comparable to DME engines [1,6].

5. REACTOR DESIGN

The engine experiments with fumigation reported in the literature were performed with synthetic DME from the bottle. The reactor design problems for these concepts with DME production on-board have not been solved, especially transient operation and cold start compatibility are a challenge.

In Figure 4 the heating-up behaviour of a reactor is calculated, based on a pseudo-homogeneous heat transfer model. The reactor is flowed through by hot gases produced by MeOH combustion in an appropriate burner. The calculation is based on a catalyst volume of approx. 1,5 litres, which is determined from the experiments with g-Al_2O_3 and a DME requirement for running a 180 kW engine with DME fumigation.

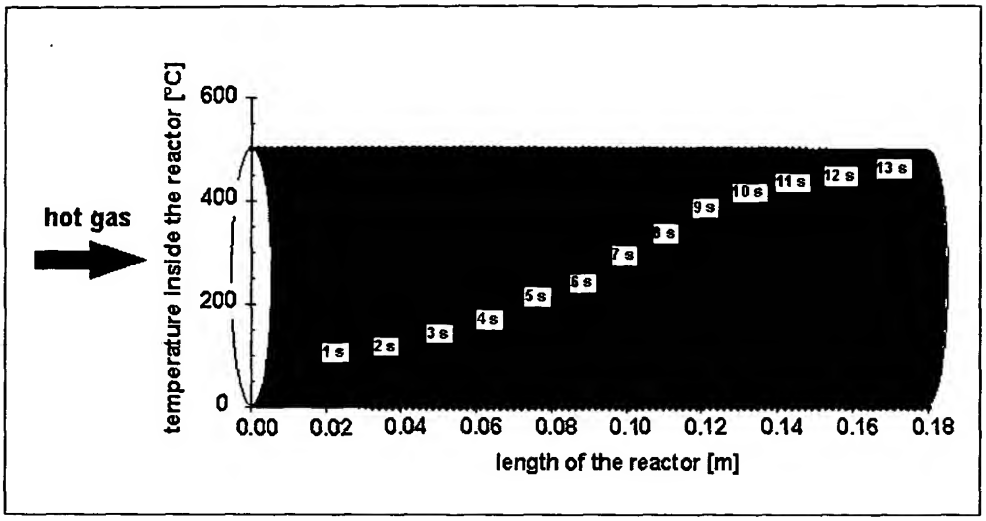

Fig. 4: Heating-up behaviour of the reactor.

A time of approx. 13 s is needed to warm up the reactor from 273 K to 573 K, the operating temperature of the g-Al_2O_3 catalyst.

The preheating time is in acceptable order of magnitude for the application onboard. In an experimental set-up the start phase and load changes will be tested. The heating-up behaviour of the reactor depends on the reactor design, which will be investigated in further experiments.

6. CONCLUSION

For the use of MeOH in the diesel engines, promising concepts are available, i.e. fumigation and torch ignition. The requested conversion rate can be achieved by using a suitable catalyst (g-Al_2O_3). The reactor design problems for these concepts have not been solved yet. Potential solution to these problems are available.

7. REFERENCES

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[6] Y. Sato et al., *Combustion and NOx Emission Characteristics in a DI Methanol Engine Using Supercharging with EGR*, SAE paper 971647.